RESEARCH, DEVELOPMENT & TECHNOLOGY TRANSFER
QUARTERLY PROGRESS REPORT

Wisconsin Department of Transportation
DT1241 02/2011

INSTRUCTIONS:
Research project investigators and/or project managers should complete a quarterly progress report (QPR) for each calendar quarter during which the projects are active.

WisDOT research program category: ☐ Policy research ☒ Wisconsin Highway Research Program ☐ Other ☐ Pooled fund TPF#		Report period year: 2013 ☐ Quarter 1 (Jan 1 – Mar 31) ☒ Quarter 2 (Apr 1 – Jun 30) ☐ Quarter 3 (Jul 1 – Sep 30) ☐ Quarter 4 (Oct 1 – Dec 31)
Project title: Laboratory Study of Optimized Concrete Pavement Mixtures		
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WisDOT project ID: 0092-13-04	Other project ID: PRJ63JN	Project start date: 8/1/2012
Original end date: 1/31/2015	Current end date: 1/31/2015	Number of extensions: 0

Project schedule status:
☒On schedule ☐On revised schedule ☐Ahead of schedule ☐Behind schedule

Project budget status:

Total Project Budget	Expenditures Current Quarter	Total Expenditures	% Funds Expended	% Work Completed
199185	80383	126591	64	40

Project description:

The Wisconsin Department of Transportation (WisDOT) continues to investigate the feasibility of optimization of paving mixtures as a means to improve the engineering properties, lower the required cementitious materials content, reduce cost, and minimize the environmental impacts. Previous research conducted by WisDOT concluded that concrete produced with reduced cementitious materials content had an adequate durability; however, these mixes frequently demonstrated poor workability. As a result, a multi-faceted approach to optimizing mixture proportioning for low-slump mixtures used in concrete pavements is needed for WisDOT to realize the benefits related to the use of lower cementitious materials contents. This approach includes the use of supplementary cementitious materials (SCMs), optimized aggregate gradations, and the use of superplasticizers (high-range water reducing, HRWR admixtures). Current WisDOT practice minimizes the use of portland cement through replacement with SCMs, but does not address the use optimized gradation or superplasticizers. Therefore, additional research is needed to support the development of specifications inclusive of the aforementioned factors to improve the performance and sustainability of concrete paving mixtures used in Wisconsin. This research project evaluates the feasibility of expanding current specifications to incorporate optimized superplasticized concrete in sustainable concrete paving applications.

The goal of this study is to produce guidelines for optimized concrete mix design by evaluating the performance of a range of concrete mixtures. The proposed performance evaluation of optimized concrete will include workability (slump and VB-test), air content, unit weight, compressive and flexural strength, freeze-thaw resistance, and rapid chloride permeability in accordance with relevant AASHTO/ASTM standards. The results of the research will be used to recommend the aggregate gradations and dosage of superplasticizers/HRWR admixtures that will accommodate the use of reduced cementitious materials for the low-slump concrete paving mixtures.

To provide the comprehensive optimization of superplasticized concrete, the proposed project will focus on the following objectives:

1. Develop a detailed, final testing matrix for comprehensive testing of aggregate gradations, SCMs and HRWR admixtures in concrete.
2. Evaluate and compare the composition, microstructural features, and physical properties of different types of cementitious materials essential for their compatibility with HRWR admixtures affecting their performance in concrete.
3. Evaluate the effect of HRWR admixtures on the fresh properties and mechanical performance of concrete.
4. Evaluate the effect of aggregate gradations on the fresh properties and mechanical performance of concrete.
5. Evaluate the effect of SCMs and HRWR admixtures on the stability of air void system, fresh properties, mechanical performance, and durability of concrete.
6. Develop and recommend for practical application an express-method capable of evaluating the performance of SCMs and HRWR admixtures in concrete.
7. Provide Life Cycle Analysis of sustainable optimized concrete paving applications based on the experimental results; submit a final report and recommendations for future work and revision of current specifications.

Progress this quarter

During the 2nd Quarter of 2013, the optimization of aggregate combinations and chemical admixtures in concrete mixtures with low cementitious materials quantities (470 lb/yd^3 [279 kg/m^3]) was investigated.

This work was focused on the compatibility of superplasticizers, supplementary cementitious materials (SCMs) and AE additives in concrete with the aim to select the best performance in superplasticized portland cement- and blended (with SCMs) cementitious systems and subsequent durability testing. The investigation of the combined effects of aggregates proportions, HRWR, and air entraining admixtures was performed. The effect of chemical and mineral admixtures on mechanical and fresh properties of pastes, mortars, and concrete mixtures with supplementary cementitious materials (SCMs) was investigated for one type of portland cement and aggregate combination. All these concrete mixtures were proportioned, mixed, cured and tested according to the WisDOT and ACI specifications.

The addition of selected air-entraining admixture(s) on superplasticized pastes incorporating different SCMs (fly ash C, fly ash F, slag cement/ground granulated blast furnace slag) was investigated by testing 51 cement pastes for flow and density. For these tests, the dosage and type of air-entraining admixture was varied. Additionally, 42 similar portland cement pastes with the optimal air-entraining admixture and with different dosages and different types of plasticizers/superplasticizers were tested for mini-slump/flow properties.

The effect of different quantities of air-entraining admixtures on superplasticized mortars was investigated by testing flow, compressive strength, and heat of hydration of 18 mixtures without SCMs. The isothermal calorimeter (TAM Air) was used to detect the rate of heat release from a hydration mixture due to hydration and so correlate setting characteristics, compatibility of admixtures and binding materials, early-strength development, the effect of chemical admixtures. The effect of air-entraining admixtures and SCMs was investigated by testing an additional 29 mortars using similar testing protocol.

Next, 67 concrete mixtures with admixtures were produced using a smaller batch (with a volume of 20 liters) to test and optimize the fresh and hardened properties of concrete such as air content, fresh density, and mechanical behavior in the hardened stage. From these mixes, 17 were produced with different types of plasticizers/superplasticizers selected based on mortar and paste test results. 24 additional concrete mixtures with different types of chemical admixtures and dosages were produced and tested. Finally, 26 additional mixtures with SCMs (fly ash C, fly ash F, slag cement/ground granulated blast furnace slag) were also tested and the effect of these minerals on the aforementioned properties was observed. Additional work that was performed during the quarter included monitoring of aggregates for moisture content. Every week aggregates were allowed to dry so that all concrete mixes would incorporate dry aggregates eliminating the fluctuation in mixing water.

Based on the results of the preliminary investigation, 12 large batches (106 liter each) with the optimal chemical admixtures and SCMs dosages were produced for detailed investigation on compressive strength development, flexural behavior, drying shrinkage, rapid chloride permeability, and freeze-thaw durability, all of which will be tested within the coming months at UW-Madison (durability) and UW-Milwaukee (mechanical testing and drying shrinkage). All tests were conducted according to relevant AASHTO/ASTM standards

Anticipated work next quarter:

Work that is expected to be completed in the next quarter includes producing optimized mixtures with further reduced cementitious materials quantities (470 lb/yd^3 [279 kg/m^3]). Concrete mixtures need to be produced for reduced cementitious materials and the feasibility of producing batches with acceptable properties will be investigated. These concrete mixtures will be proportioned, mixed, cured and tested according to the WisDOT specifications. New types of portland cement and aggregates will be obtained and evaluated for consequent testing. The remaining concrete specimens based on different cement types and very low cementitious materials content (470 lb/yd^3 [279 kg/m^3]) for the

1st phase durability investigation (using South aggregates combinations) will be completed and delivered to UW-Madison for subsequent testing.

Also, synchronizing the optimal dosage of chemical admixtures from mortars to concrete mixtures, and correlating early strength of mortar and concrete mixtures will be investigated. This follow-up step will further explore the empirical relationships between the results of express-tests and concrete properties and will evaluate the principal parameters affecting the performance.

The research team will provide the statistical analysis of experimental data; develop the relationships between the experimental factors and compare these with AASHTO/WisDOT/ACI requirements.

Circumstances affecting project or budget: None

Attach / insert Gantt chart and other project documentation Enclosed

FOR WISDOT USE ONLY

Staff receiving QPR:	Date received:
Staff approving QPR:	Date approved:

Gantt Chart / Work Time Schedule

ID	Task Name	Duration	Start
1	**Entire Project**	**653 days?**	**Wed 8/1/12**
2	**Task 1 - Literature Review**	**420 days**	**Wed 8/1/12**
3	Review literature and gather information	70 days	Wed 8/1/12
4	Update literature review as needed	350 days	Wed 11/7/12
5	Task 2 - Finalize the Research Matrix	26 days	Wed 8/1/12
6	**Task 3 - Evaluate Concrete Specimens**	**548 days?**	**Wed 8/1/12**
7	**Collect & Characterize Materials**	**65 days?**	**Wed 8/1/12**
8	Collect Cementitous Materials	50 days	Wed 8/1/12
9	**Characterize Cementitious Materials**	44 days	Wed 8/29/12
10	Identify and collect aggregates	45 days?	Wed 8/1/12
11	Characterize aggregates	30 days	Wed 9/19/12
12	**Optimization of Aggregates & HRWR**	**180 days**	**Wed 11/21/12**
13	Prepare optimized aggregates	180 days	Wed 11/21/12
14	HRWR - cement compatibility & dosages	180 days	Wed 11/21/12
15	**Optimized Mixtures**	**308 days**	**Wed 7/3/13**
16	Plastic properties	180 days	Wed 7/3/13
17	Compressive Strength	220 days	Fri 7/12/13
18	Flexure Strength	220 days	Fri 7/12/13
19	Freeze-thaw Resistance	280 days	Mon 8/12/13
20	Rapid Chloride Permeability	250 days	Mon 8/12/13
21	**Task 4 - Data Analysis**	**80 days**	**Wed 5/21/14**
22	Comprehensive data analysis	80 days	Wed 5/21/14
23	**Task 5 - Reporting**	**651 days**	**Fri 8/3/12**
24	Draft final report	50 days	Wed 8/13/14
25	Report presentation to RPTOC	10 days	Wed 10/22/14
26	Review, Revise and Submit Final Report	50 days	Wed 11/5/14
27	**Quarterly Progress Reports**	651 days	Fri 8/3/12